Climate change and NaTech events: A step towards local-scale awareness and preparedness

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Climate change and Natech events: a step towards local-scale awareness and preparedness.

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ABSTRACT

The present paper proposes a methodology that aims at supporting the awareness and preparedness of urban and local planners to cope with Natech risk, together with the availability of dedicated tools. Since most of the natural events that can trigger technological hazards are influenced by climate change (i.e. flood, heavy rains, storms etc.), Natech risk is expected to be strongly increasing in the next years. However, dedicated Natech planning actions and methods or tools to support them are still rarely available. The requirements of European Adaptation Strategy for Climate were examined considering the issues posed by the Seveso III Directive in terms of Natech, focusing on the strategies adopted in the European countries, and in particular in Italy. Based on such analysis, a 'Natech tool' dedicated to local planners was developed. Practical and easy to use methods and procedures were proposed in order to allow the use of the method by the local authorities, in the absence of sectorial experts.

KEYWORDS

Natech risk, Climate change, Local planning, Decision support system

1. INTRODUCTION

Climate change is progressively modifying the impact of natural risks (i.e. floods, storms, heat waves), which are assuming magnitude and recurrence never recorded before. National and international authorities worldwide are carrying out efforts to introduce strategies of adaptation and mitigation towards the increasing risks generated by climate change. However, the level of awareness of population, and most of all, the development of dedicated cogent legislative framework deeply differs among countries.

The higher disruptiveness of natural events is nowadays affecting also the industrial sector, both in terms of economic losses and of cascading events, resulting in specific risks for the population and for the environment. Due to worldwide industrialization, climate change, population growth, and community densification, an increase in the number and magnitude of the so-called Natech events is expected (Krausmann et al., 2017). Natech (natural disasters triggering technological accidents) events consist in technological accidents, as the release of dangerous materials from industrial installations and the consequent fires, explosions and dispersion of toxic substances, triggered by natural hazards. They are connoted by distinctive features as, i.e., multiple releases, escalation and cascading events on lifelines and networks, as electric power, natural gas and water, supply, etc (OECD, 2013). These risks are cutting across different domains and stakeholder communities that may have not much interacted (Krausmann et al., 2019). As detailed in the following, the European Union "Seveso-III" Directive (European Union, 2012) requires since 2012 to include Natech events in the major-accident scenarios considered in the Safety Report issued for the sites falling under the obligations of the Directive. However, no widely accepted approach is present for the identification and assessment of Natech scenarios, and specific guidelines for industry and regulatory authorities are not yet available (Krausmann et al., 2017). Although several research institutes and universities have developed semi-quantitative and quantitative methodologies to deal with Natech risks (Krausmann et al., 2017), the awareness of this risk among urban and land-use planners and local stakeholders that are usually of the frontline of land use planning and emergency management, is still gradually unfolding (Krausmann,2010, Salzano et al., 2013).

As far as climate change is concerned, European Commission launched the EU Adaptation Strategy for Climate in 2013. The recent Evaluation on the progress of the EU Adaptation Strategy (European Commission, 2018) demonstrated that the implementation of dedicated actions and measures varies depending on the Member state. Even single regions and cities demonstrate different levels of awareness with regard to climate change, with a general backwardness of inland areas and smaller cities. This requires that, at least in perspective, local planners and authorities will have to face on their territories the increasing impacts of Natech events triggered by climate change. To oversee the wide range of situations that could be caused by the combination of extreme climate and Natech events, local planners and local authorities should have access to a multidisciplinary knowledge supported by an interdisciplinary team of sectorial experts, including chemical, environmental and structural engineers. Unfortunately, such a team is often not available to local authorities. As a consequence, both in planning and in assessment procedures, as well as in emergency planning for local communities, potential impacts of Natech events can be dramatically ignored, with possible severe consequences on the areas impacted and on the local population.

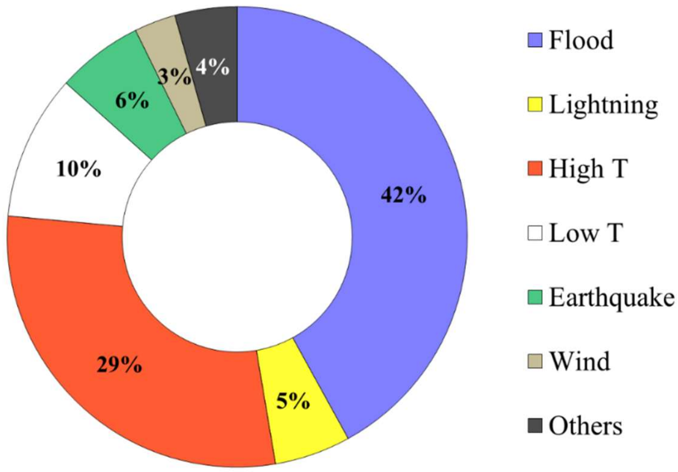
Safety of local communities in the future should cope more and more with climate change effects. The present study aims to contribute to this challenge, providing some specific approaches and methodologies to support planning and decision-making of local authorities with respect to NaTech. The proposed approach should support local authorities in the assessment and management of NaTech risk. This would improve the quality of the risk assessment procedures and consequently it would mitigate the consequences of the effects of climate change. In the following, section 2 will briefly present NaTech risk issues and EU Directives addressing the control of major accident hazards related to dangerous substances and climate change. Section 3 presents the Natech framework from the point of view of local and land-use planners. In Section 4 a possible 'Natech tool' intended for the use of local planners is proposed.

2. NATECH EVENTS

Availability of past accident data concerning Natech events is still poor and not harmonized between the different European countries. Regional and local communities usually do not have a dedicated registry of industrial facilities in areas exposed to natural hazards zones, or a systematic tracking of potential or past Natech accidents. Hence, there is usually no baseline to compare risk trends over time (Krausmann et al., 2019). Wherever there are no legal obligations for reporting accidents, information is frequently unavailable. Even where accident reporting is mandatory, it often applies only to accidents whose impact exceeds a predefined severity threshold, as in the case of Seveso sites. Similarly, for data from public sources there is a bias in media coverage towards major accidents: since low-consequence events or near misses rarely make the news, they are frequently lost from the lessons-learning process (Krausmann et al., 2019).

Recently, a specific database of Natech events was built and populated by Casson Moreno et al. (2019), extracting all the 412 Natech events reported by the ARIA Database (BARPI, 2019) at the time. Figure 1 shows the natural events that caused Natech events, evidencing that these were more frequently caused by flood and extreme temperatures, although also earthquakes have part of the share. Except for earthquakes, it is worth to notice that all the natural events that can trigger a technological hazardous event are strictly correlated to meteorological conditions, i.e. micro- to meso-scale extreme weather and atmospheric conditions that last from minutes to days [EM-DAT,2019], such as lightning, storms or extreme temperatures.

Figure 1: Natural events causing technological accidents for 412 Natech events reported in the ARIA database.



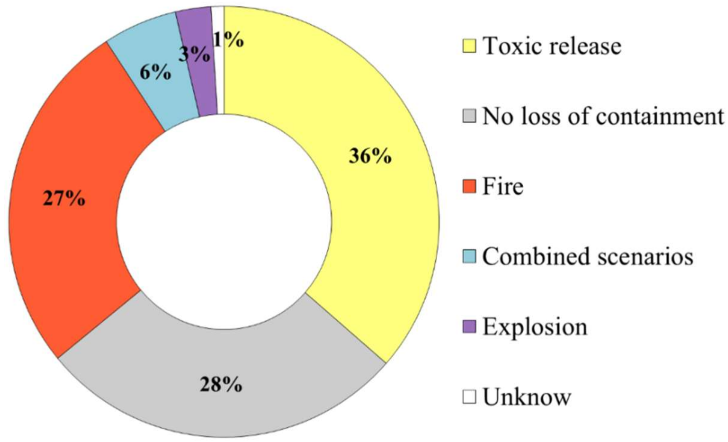
The evolution of Natech events, potential patterns in accident dynamics and final consequences were analysed in several studies (e.g. see Antonioni et al., 2009, Cozzani et al., 2009, Krausmann et al., 2011, Gyenes, 2014, Necci et al., 2018, Misuri et al., 2019). In these studies, an effort was made to analyse the past events in order to identify recurrent types of accidents, the most hazardous natural events, vulnerable items etc. Table 1 summarizes the main findings, concerning the specific technological scenarios triggered by natural events.

Table 1: Natural events and consequences on industrial assets

NATURAL HAZARD	***CONSEQUENCES***
Earthquake	Damage to industrial facilities through direct shaking impact or soil-liquefaction-induced ground deformations. Damage modes: elephant-foot- or diamond buckling, stretching or detachment of bolts, deformation of failure of columns and support structures. Failure of flanges and pipe connections, failed tank shells or roofs, possible tank overturning or collapse.
Flood	Displacement of equipment consequent to flood-induced buoyancy and water drag that can strain or break connections between pipework and equipment or cause pipelines to rupture. Minor leaks, or more severe ruptures and continuous releases; collapse or implosion of tanks due to the flood pressure; ruptures caused by floating objects.
Heavy rainfall	Sinking of tank roofs; flooding of the site due to sustained rainfalls, for insufficient water drainage or increased groundwater levels. Dispersion of the released substances; the release may exceed the capacity of the secondary containment (especially if combined with localized flooding).
Lightning	Direct damage to the equipment e.g. by causing the rupture of tank shells, pipes and connections, or impact on safety and electrical control systems. Ignition of flammable vapours on the tank roof.
Storms	Threat to the integrity of an industrial installation. Fires, explosions and the dispersion of chemicals in the environment.
Extreme temperatures	Extremely high temperatures → ignition of flammable or even just combustible materials stored outside. Pressure increases in storage facilities, including railcars, where pressure relief valves can actuate to prevent the equipment or vessel from bursting. Extremely low temperatures or long spells of intense cold → freezing and bursting of pipes, the weight of the ice can also provoke structural damage to equipment and break pipes.

The final scenarios recorded in the 412 accidents retrieved by Casson Moreno et al. (2019) from the ARIA database are shown in Figure 2. Most of the events (71 %) are characterised by a loss of containment from equipment or pipes, typically of toxic or eco-toxic substances (36 %), followed by the release of flammable substances that led to either fire (in 27 % of the cases) or explosion (3%). In 5 % of the cases, the final scenario was a combination of the previous ones listed. In 28 % of the records, no loss of containment was reported but for 82 accidents out of 412 (≈ 20 % of the total) damage to equipment was observed; the rest of the cases analysed are near misses.

Figure 2: Final consequences of Natech events reported for 412 accidents recorded in the ARIA database.



As far as the vulnerability towards Natech events is concerned, according to the post-accident analyses reported e.g. by Antonioni et al., 2009, and Krausmann et al., 2017, the items more prone to the impact of earthquake, flood and lightning resulted the atmospheric storage tanks, and in particular those with floating roofs.

3. MAJOR ACCIDENT HAZARD AND ADAPTATION TO CLIMATE CHANGE: A REGULATORY VIEW

Natech risk related to facilities storing or processing relevant amount of dangerous substances are addressed by the EU legislation (European Union, 2012). Floods are addressed by the EU Flood Directive (European Union, 2007). Other natural hazards as storms and hurricanes are not addressed by specific regulations neither at a European nor at national level. Furthermore, an integrated approach to the assessment and management of the challenges related to climate change is still lacking for most natural hazards. As previously mentioned, in 2013 the EU adopted a Strategy for Climate Adaptation to sustain and promote important actions towards awareness, adaptation and planning with respect to climate change in all the EU Member States. However, since important Directives as those dedicated to Floods and Seveso establishments were released before the adaptation strategy, the existing legislation for urban and land use planning and emergency management still not entails specifically climate change effects.

3.1 Seveso-III Directive (2012/18/EU)

In Europe, industrial facilities detaining hazardous substances beyond given thresholds fall under the obligations of the Seveso-III Directive on the control of major-accident hazards related to dangerous substances (European Union, 2012). The Directive requires the so-called upper-tier to issue a safety report (art. 10), that should identify major-accident scenarios and assess the preventive and protective measures adopted. In addition, both upper-tier and lower-tier installations have to provide the authorities with all the necessary information (art. 7) to ensure an adequate emergency management (art.12) and land use planning around the site (art. 13). Possible domino effects, that are often associated to Natech events, are addressed by the Directive with a dedicated article (art. 15). Natech events are explicitly considered in the introductory part of the Directive (point 15: “*The risk of a major accident could be increased by the probability of natural disasters associated with the location of the establishment. This should be considered during the preparation of major-accident scenarios*”) and in Annex II, addressing the minimum data and information to be considered in the safety report, where Section 4.a, at point (iii) requires to include natural cases among those triggering the possible major-accident scenario considered in the safety report. Thus, Seveso Directive should be considered the most important legal act at EU level concerning Natech risk assessment and control (Krausmann et al., 2017).

As far as land-use planning related to the application of Seveso III Directive and its previous versions is concerned, the EU member states adopted different approaches to estimate safety distances and impose bindings on the possible land use around Seveso plants. After issuing Seveso-III Directive, Natech events are currently considered in safety reports issued for upper-tier installations, but no clear guidance about their integration in the planning policies is provided. Therefore, local administrators rarely consider these events, in particular when lower-tier installations or installations not falling under the obligations of the Directive are considered. Indeed, nature and environment are still mostly defined as vulnerable elements, and the complex interaction with the industrial plants, both Seveso and non-Seveso, is usually not investigated in sectorial risk plans.

Krausmann et al., 2019, evidence that some countries adopted legal infrastructures to address NaTech risks (i.e. France and Germany have active Natech risk reduction programs based on legal acts for chemical accident prevention), but regulations and guidance on how to implement the requirements stipulated by law, and specific guidelines for Natech risk reduction, are rare in the EU and in OECD countries. The difficulty in elaborating dedicated guidelines is also related to the multi-disciplinarity of the problem: knowledge and responsibilities in Natech Risk Management (NRM) rely on different actors (i.e. industry, ministries in charge of labour, national, regional, local authorities for civil-protection or environmental issues) and disciplines (safety engineering, land use planning, disaster management etc.). Unfortunately, information does not flow freely and effectively among these actors. This often causes a fragmentation of knowledge and responsibilities, and, consequently, an underestimation or even a complete ignorance of Natech risks (Krausmann et al., 2019).

Another open problem in NRM is related to installations not falling under the obligations of the Seveso-III Directive. Actually, some industrial activities may involve the use of hazardous substances in quantities that are lower than those addressed by the Directive, but whose release following the impact of a natural event may still cause non-negligible technological hazards. While the hazard due to Seveso installations is usually thoroughly mapped, local administrators have little or no information on other installation where dangerous substances may be present. Actually, non-Seveso industrial facilities share information about the substances they store or handle, or about their production processes only if they fall under the obligations of Directive 2010/75/EU on industrial emissions (European Union, 2010). Even if local planning authorities are not directly in charge for the Environmental Integrated Authorization (EIA) process, usually regional or national authorities share with them the information about such activities and local authorities are usually involved in the authorization process.

It should also be remarked that EU Directive 89/391/EEC of 12 June 1989 for Safety and Health of workers (Council of the European Communities, 1989) and following amendments, requires industrial activities to assess the risks related to Health and Safety of the workers, including major accident hazards and thus possible Natech events. However, this analysis is not necessarily shared with local authorities.

3.2 EU strategy on adaptation to climate change

The aim of the EU strategy on adaptation to climate change is to make Europe more climate-resilient through the enhancement of the preparedness and capacity of all governance levels to respond to the impacts of climate change. The Commission published the results of the evaluation of the strategy in November 2018 (European Commission, 2018). Although the strategy delivered its objectives, Europe resulted still vulnerable to climate impacts within and outside its borders. The evaluation identified the areas where more work is needed to prepare vulnerable regions and sectors to climate change, through a detailed analysis of the actions undertaken by each EU Member State. An Adaptation Preparedness Scoreboard was prepared, based on the assessment of 11 indicators and sub-indicators (European Commission, 2018a), as shown in Table 2.

Table 2: EU Adaptation Preparedness Scoreboard

No.	***Indicator***
Step A: Preparing the ground for adaptation	
1	Coordination structure
2	Stakeholders' involvement in policy development
Step B: Assessing risks and vulnerabilities to climate change	
3	Current and projected climate change
4	Knowledge gaps
Step C: Identifying adaptation options	
6	Identification of adaptation options
7	Funding resources identified and allocated
Step D: Implementing adaptation action	
8	Mainstreaming adaptation in planning processes
9	Implementing adaptation
Step E: Monitoring and evaluation of adaptation activities	
10	Monitoring and reporting
11	Evaluation

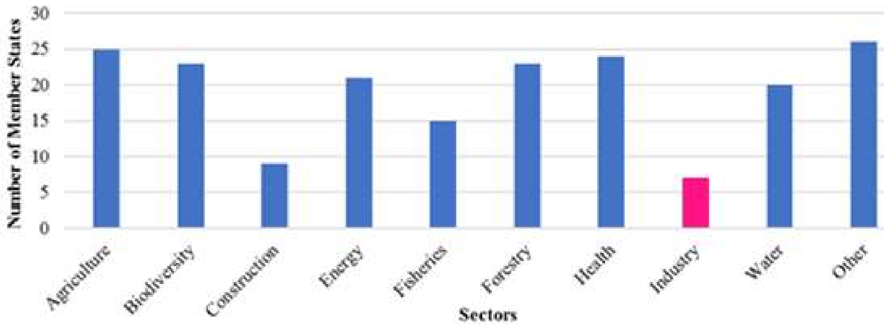
The answers provided by the Member states for the Adaptation Preparedness Scoreboard (European Commission, 2018a) are in some cases relevant to understand the achievements in Natech Risk Management. A major preparedness in relation to the risks influenced by climate should include the preparedness and awareness towards technological hazards triggered by natural events. In particular, the following sub-indicators could give evidence on if and how Natech risk was duly taken into account in each national climate adaptation framework:

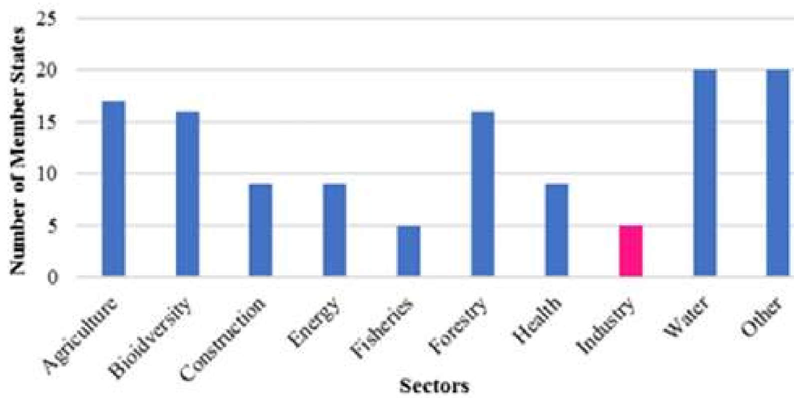
- ***3c**: Sound climate risks/vulnerability assessments for priority vulnerable sectors are undertaken to support adaptation decision making*
- ***8c**: Key land use, spatial planning, urban planning and maritime spatial planning policies take into account the impacts of climate change*

As far as indicator **3c** is concerned, climate risk and/or vulnerability assessments for priority sectors were developed by at least 22 Member States. Industry, and consequently Natech events, was considered by less than 10 member states. Concerning indicator **8c**, 15 Member States implemented land use, spatial, urban and maritime planning policies that explicitly address climate impacts and require or encourage adaptation. Only 6 Member States have national policy instruments that promote adaptation in the industrial sector.

The graphs reported in the following Figure 3 represent the number of States that: adopted climate risk/vulnerability assessments for specific sectors (indicator **3c**); implemented specific adaptation policies for specific sectors (indicator **8c**). The industrial sector is highlighted in pink color.

Figure 3: EU Member states that adopted climate risk/vulnerability assessments and specific adaptation policies for INDUSTRIAL SECTOR (in pink)





The evaluation on the EU Adaptation Strategy shows different levels of awareness and preparedness among the Member States. While the importance of collecting data and investigating the phenomena related to Climate change seems to be uniformly recognized, the adaptation of the legislative corpse of each country is undergoing some difficulties. Risk assessment strategies in many cases do not recognize yet the role of Climate change. No incentives have been activated to promote adaptation and most of all, in the field of technological hazards triggered by natural events, very few countries have carried out effective policies to prevent and reduce the increasing risk due to climate change.

3.3 A glance at the Italian National Adaptation Plan (NAP) and Natech

The Italian National Adaptation plan was analysed as an example, to provide a representative insight of the actual significance of the strategies for the adaptation to climate change promoted by the EU member states.

In December 2017, Italy issued the first draft of the "Piano Nazionale di Adattamento ai Cambiamenti Climatici" (PNACC), the Italian National Adaptation Plan (NAP) required to each Member state to implement the EU Adaptation Strategy. The purpose of the NAP is to guide Ministries, Regions, and local authorities for the integration of adaptation criteria into policy processes. Italian NAP was developed in charge of the Italian Ministero dell'Ambiente e della Tutela del Territorio e del Mare; representatives of local and regional institutions were involved in the Institutional Panel established to support elaboration of the National Adaptation strategy. In the meantime, some subnational authorities (i.e. Regions as Lazio and Abruzzo) and some municipalities already promoted adaptation through specific plans or documents: i.e., 220 municipalities have already committed to adaptation planning and actions through the framework of the Covenant of Mayors 22 (European Commission, 2018a).

Italian NAP (Centro Euro-mediterraneo sui Cambiamenti climatici, 2017) recognizes the problem related to Natech events among the Sectoral vulnerabilities related to Climate change: "*The increase in number and impact of extreme meteorological events, and the consequent lightning, floods and landslides, could directly* *have repercussions on the industrial activities and infrastructures located in the Po Valley, Sardinia and Tyrrenhian coasts. The productive capacity of these installations could be negatively affected by the extreme meteorological events, and the release of hazardous substances could enhance the risks both for the population and the environment. Although in the past Natech events have been rare, they are now increasing, and the modern societies are more vulnerable because of the high density of population and higher number of Major risk industries and infrastructures*".

Therefore, NAP proposes sectoral measures and good practices to ensure climate change adaptation for the industrial sector, also identifying the authorities in charge for the action (Centro Euro-mediterraneo sui Cambiamenti climatici, 2017). The sectoral measures identified by NAP are reported in Table 3.

Table 3: Italian National Adaptation Plan: sectoral measures for Natech events.

Measure ID	Description	Authorities in charge
IP001	Creation of a Scientific board aimed at elaborating a Specific risk map for Hazardous industries and infrastructures	Presidenza del Consiglio dei Ministri
IP002	Identification of the vulnerable areas (subjected to floods, landslides, lightning) in proximity of hazardous industries and infrastructures	Basin authorities, authorities in charge for the control of hazardous installations
IP003	Integration of the adaptation in the urban and land use planning tools to identify adequate areas for new hazardous industries or infrastructures	Local administrations, Prefectures
IP004	Draft of dedicated Guidelines for the authorities	Authorities in charge for the control of hazardous installations
IP005	Sensibilization and information to industries about the necessity to implement adaptation actions for climate change	MiSE – Ministry of Economic Development, MATTM – Ministry of the Environment, Regions
IP006	Commitment for the operators to revise their Safety and Environmental Management Systems taking into account the natural events correlated to Climate change that could trigger a NaTech event	MATTM – Ministry of the Environment, Regions
IP007	Specific training for urban and land-use planners for NaTech risk management	MIT - Ministry of Infrastructures, Regions, ANCI - National Association of Italian Municipalities, Civil Protection
IP008	Integration of NaTech scenarios in the existing Emergency Planning for hazardous installations	Local administrations
IP009	Adoption of early warning systems in areas interested by hazardous installations and infrastructures	National Civil Protection
IP010	Specific training for emergency planners and managers in relation to NaTech emergencies, aimed at increasing the preparedness in relation to multi-risk events	MIT - Ministry of Infrastructures, Regions, ANCI - National Association of Italian Municipalities, Civil Protection
IP011	National programme of interventions to support the operators for the improvement of the prevention and management of NaTech risks (mandatory insurance, compensations, etc.)	Presidenza del Consiglio dei Ministri

The yellow lines in Table evidence the measures directly in charge to the local administrations. However, local administrations will be for sure involved also in the training phases (see Measures IP007 and IP010), as well as in the actions aiming at the control of hazardous installations (i.e. Measure IP002).

Despite the accuracy of the measures defined for Natech and other sectors, the answers to the Adaptation scoreboard reported in the Country fiche for Italy (European Commission, 2018b) evidence a slow or inexistent translation of the NAP in adaptation actions. I.e., National Disaster Risk management plan does not take into account climate change impacts and projections, and no Guidelines for Climate change adaptation are available. However, the actions carried out do not identify the industrial sector as a priority.

Some of the main criticalities emerging from the answers to the Adaptation Scoreboard (European Commission, 2018b) are reported in Table 4.

Table 4: Criticalities emerging from the answers to the Adaptation Scoreboard [14].

Adaptation strategy	Execution	Motivation
8b) Prevention/preparedness strategies in place under national disaster risk management plans take into account climate change impacts and projections	NO	Planned Actions to better manage different disaster risks due to climate change, but time and modes of the implementation process into national disaster planning are not clear.
8c) Key land use, spatial planning, urban planning and maritime spatial planning policies take into account the impacts of climate change	NO	NAP should provide institutional guidance to national and local authorities, for the integration of adaptation measures within policy processes and spatial planning, but the guidance has not been defined or implemented at national level
8d) National policy instruments promote adaptation at sectoral level, in line with national priorities and in areas where adaptation is mainstreamed in EU policies	IN PROGRESS	Adaptation activities implemented for agriculture, water use, forests, human health, flood risk, desertification and drought, coastal areas, biodiversity, tourism, urban settlements.
9c. Procedures or guidelines are available to assess the potential impact of climate change on major projects or programmes, and facilitate the choice of alternative options, e.g. green infrastructure	NO	It is unclear whether guidelines for assessing the climate impacts on projects/programmes have been developed and promulgated

Unfortunately, it is not possible to verify if the gaps reported in the previous table have been addressed, since after 2017 no further updates concerning the implementation of the Italian NAP were released by the Italian government. The absence of a monitoring system makes even more difficult to follow the implementation of NAP measures and strategies, as shown in Table 5 (European Commission, 2018b).

Table 5: Impact of the absence of a monitoring system on the implementation of NAP measures and strategies [14].

Adaptation strategy	Execution	Motivation
10a. NAS/NAP implementation is monitored and the results of the monitoring are disseminated	NO	Information on adaptation actions are not systematically collected, beyond fulfilling the reporting obligations under the UNFCCC. A monitoring system to evaluate NAP implementation progress is neither in place at the national level nor at the regional level
10b. The integration of climate change adaptation in sectoral policies is monitored and the results of the monitoring are disseminated	NO	A system to monitor sectoral adaptation activities and their related expenditures, or to report adaptation activities, has not been established
10c. Regional, sub-national or local action is monitored, and the results of the monitoring are disseminated	NO	Climate adaptation reporting is taking place at regional, sub-national and local levels, without an effective monitoring and dissemination.

Therefore, despite the NAP, in Italy the adaptation to climate change seems to be still left to the initiatives of regional or local authorities. An integrated and coherent system for the prevention, adaptation and management of climate change, able to integrate and complete urban and land-use plans, and emergency procedures, is still missing. The result is that often, while risks related to climate change continue to increase, citizens and administrations are left to face them with obsolete planning and emergency tools.

4. LOCAL PLANNING APPROACH TO RISK AND ADAPTATION

As remarked by Measham et al., 2011, the impacts of climate change are experienced locally, and local governance systems are often the responsible and legitimate entity for managing such impacts. Therefore, at the local scale, municipalities (also known as local governments) represent a core institutional unit that are increasingly recognized as having a critical role to play in climate adaptation. Local authorities should be responsible to ensure an effective implementation and application of measures against risks, but several different but correlated causes often constitute an obstacle for the reach of a concrete protection.

Local authorities' crucial role is largely related to the fact that they detain planning powers: they can orient the future development of the urban and natural landscape, considering its social and economic needs, and at the same time they are responsible to protect the citizens, in example through the local Emergency plans. Therefore, local authorities deal with risks, both natural and anthropic, with very different scopes: on one side, the local urban plans incorporate the information contained in Superior authorities risk assessment plans for planning needs; on the other side, risks are considered to develop specific actions for emergency (areas of recovery, etc). However, Land-use and Emergency plans, though sharing the same basic risk indications, are not mutually linked in the matter of long-term risk management: one is specifically related to the territory and the other to emergency, without establishing common preventive structural measures that could contribute to reduce risk and prevent emergency (Pilone et al., 2016). As confirmed by Wang, 2012, the planning field scarcely involves itself with disaster management, and the latter has never been seen as part of the land use planning. However, the growing escalation of extreme climate-related events is making imperative the integration of land-use planning and disaster management, with a shift from emergency response to hazard mitigation (i.e. through urban policy, land use strategy, watershed management etc.). Despite the growing attention to the theme of climate change, and the settlement of national adaptation strategies (see Par. 3), still some difficulties remain at a local level:

1. Local authorities currently act as implementing agents for higher levels of government (Measham et al.,2011), and in many instances the national legislations have yet to incorporate concrete actions for the adaptation to climate change, which subsequently affects the legal mandate of local government to adapt. Therefore, a lack of attention to climate change at the national and state levels lead to a lack of attention to climate adaptation at the local level (Amundsen et al. 2010). Many studies also evidence a problem of responsibility in front of the new challenges imposed by climate change: i.e. Lumbroso and Vinet, 2012, underline, in relation to flood management, that there are aspects for which it is not clear who should take the lead, there are some responsibility gaps between the authorities in charge that make the management of risks less efficient. Measham et al., 2011, consider that local government, like other institutions, operates within an 'institutional void', where the complexity of governance poses challenges to clear definitions of institutional roles and responsibilities, resulting in ineffectual policy development.
2. The capacity of local governments to efficiently cope with the challenges of climate adaptation is reduced by the scarce technical preparation. I.e., concerning Na-tech field, a questionnaire made by Krausmann and Baranzini, 2012, among public decision-makers evidenced the need of raising awareness and improving risk communication at all levels of government (national, regional, and local); the lack of Natech-specific technical codes and guidelines for Natech risk assessment; the need of Natech risk maps for informing land-use planning and emergency-management decisions. The lack of awareness about the risks and the potential available tools to cope with them is denounced also by Lumbroso and Vinet, 2012: 'too few people are being trained to replace the ageing skilled workforce, and too few are acquiring the technical and managerial skills required to get full value from new techniques and technologies.' This lack of technical capacity can in some cases discourage the use of new methods that are not viewed as being 'mature'. In the face of low-probability events, some organizations may suffer from poor intelligence gathering and processing or even a 'it can't happen here' mentality.
3. The risk plans, and consequently land use and emergency planning, should be constantly keep updated, because risk is a dynamic factor: but, as reported by Prabhakar et al., 2009, 'regular revision

of disaster management plans is far from reality in many countries as hazard and vulnerability assessments are done when funds are available through a project and any revision is not possible after the termination of the project. Many revisions were done only after a major disaster has struck'. The difficulty of the local authorities in updating the plans and having an adequate preparation strictly depend on their budget: indeed, the need for climate adaptation is in contrast with other local needs that appear more urgent. Even when the need for climate adaptation is acknowledged in the conceptual realm of strategic planning, it may be underrepresented when it comes to allocating scarce resources (Measham et al., 2011).

The political nature of local government means that all decisions, including climate adaptation, are affected by political interests and competing preferences vying for support at the municipal scale. However, it is important to recognise that allocating adequate resources and setting goals is strongly tied to the platforms of elected officials, which means that the support, or lack of it, from political leaders can enable or stifle climate adaptation at the local scale (Measham et al., 2011).

5. NATECH TOOL FOR LOCAL PLANNERS

The analyses reported in Par. 3 and Par. 4 show that, currently, local land-use planners cannot be considered adequately aware of Natech risk, in particular in relation to its foreseen increase due to climate change. At the same time, the adaptation to the challenges of climate change in terms of national legislative actions, compensation mechanisms, sectorial risk guidelines is proceeding with different velocities for EU member states, and the effective implementation at local level of dedicated measures is an objective difficult to reach even for the most advanced countries.

As far as Natech is concerned, some risk assessment methodologies have been settled for selected natural hazards and industrial activities but, as evidenced in the literature (Krausmann et al., 2017; M. Cardarilli et al., 2019), many criticalities are still hindering a widely shared approach to Natech Risk Management (NRM). In particular, the methodologies are not widely in-use, suggested reference accident scenarios may still lack of detail, studies on the direct and especially indirect impacts to the communities, economy, and environment are scarce, resilience aspects are not accounted for. The methodologies elaborated till now are mainly focused on the protection of the population and of the assets from the point of view of regulatory authorities or of company managers. Rarely the management of Natech risk is analysed from the point of view of local urban and land-use planners and managers.

In the present section, a 'NaTech suite' was developed for local planners and administrators to:

- quickly identify potential sources of Natech events and vulnerability of industrial sites;
- improve knowledge about possible specific Natech scenarios;
- assess the tolerability of possible Natech scenarios with the existing land and urban functions.

This approach cannot substitute quantitative risk analysis but aims at filling the existing gaps at local level, providing at least a screening approach, in the absence of a harmonized legislation concerning Natech risk and its territorial relapses.

The proposed steps are:

1) Identification of Natech vulnerable sites based on a checklist
2) Questionnaire to the companies managing the identified sites
3) Semi-quantitative methodology to assess the impact of Natech risk
4) Identification of Natech risk scenarios (Integrated Quantitative risk-assessment)

5.1 Checklist of potential Natech prone industries

As remarked in section 3.1, besides Seveso sites, several other industrial sites and activities may cause Natech scenarios. Unfortunately, if the facility is not falling under the obligations of the Seveso directive, data related to the type and quantities of substances detained, type and age of items and productive processes are rarely available to local authorities.

Therefore, a checklist to quickly identify potential Natech prone industries was drafted. The checklist was based on:

1. the list of activities subjected to EIA authorization according to the EU directive on industrial emissions (European union, 2010a)
2. a list of potentially hazardous activities relevant to the application of the Seveso Directives (adapted from Boverket, 1995.

Table reports an example of the 'Guide-row' for the proposed checklist: for each activity, the items potentially vulnerable to Natech risk are identified, together with the most hazardous natural event for them. Possible consequences are indicated too. Expert judgement is needed to identify the plants that could generate the worst NaTech events. The checklist will allow the planners to understand if there is the potentiality of a Natech event on their territory, and to decide if it will be necessary to proceed with the application of the subsequent steps of the Natech suite. A wider extract of the checklist is reported in the Technical annex.

Table 6: Example of Checklist of potential NaTech prone industries (extract)

Industrial activity	***IPPC***		***NOSE-P process***	***Main substances***	***Items / processes vulnerable for NaTech risk***	***Items position***		***Vulnerable to:***	***Possible consequences***
	Cod.	***Description***				***Inside***	***outside***		
TEXTILE INDUSTRIES									
Preparation and spinning of textile fibers	6.2 6.7	Plants for pre-treatment or dyeing of fibers or textiles	Manufacture of textiles and textile products	1) Sizing: acrylic or resin-like starches or polyvinyl alcohol or carboxymethyl cellulose 2) Purge: sodium hydroxide, sodium carbonate 3) Bleaching: chlorine or perborate compounds and phosphates 4) Dyeing: Colorants	Process basins for Sizing; Purge; Bleaching and Dyeing	**x**		Earthquake	Cracking of process basins; possible leakage and pollution of soil and waters in case of absence / breaking of containment basins
					Plants for the physical and chemical treatment of waste water		**x**	Earthquake Floods	Cracking / braking of the basins Overflowing in case of flood / heavy rain Possible pollution soil / water

5.2 Natech questionnaire

The second step of the proposed 'Natech suite' consists of a questionnaire to be sent to the companies managing the potentially vulnerable sites identified through the checklist.

The questionnaire is composed by three sections that investigate respectively:

1) storage methods and items potentially exposed to Natech risk;
2) past accidents occurred on the site;
3) environmental impact adapted from the methodology proposed by Provincia di Torino, 2010).

The in-depth questionnaire, shown in Table 7, can provide effective answers on the hazardousness of the plant and on its exposure to Natech risk, guiding the Municipalities in better identifying the possible actions and priorities of intervention.

Table 7: Natech questionnaire

A) STORAGE CONDITIONS & NATECH ITEMS

1) With reference to the hazardous substances detained, please indicate in detail the storage conditions of each hazardous substance, describing type, capacity, quantity and containment measures adopted.

Hazardous substance	*Stored in (container type)*	*Number of containers or total capacity*	*Single Container Capacity*	*Position: Inside, outside, outside under coverage, underground, etc..*	*Containment measure adopted for the container (basin, waterproof ground etc.)*

2) Please report if the following items are present:

Underground pipelines, pipelines passing on not-waterproofed soil.	*Description (length, width, substance transported, protection measure)*
Long and slim structures (torches, chimneys, cooling and distillation towers etc)	*Description of the structure and its function*
Open-air water treatment basin / liquid waste storage	*Description of the installation and related preventive measures*
Hazardous waste storage	*Description of the quality and quantity of stored waste, and related containment measures*

B) PAST ACCIDENTS

3) Please report a list of the accidents occurred in the last 20 years that caused the release of hazardous materials

Date	*Item interested*	*Accident description*

4) Please describe damages caused by: flood events, extreme climate events, earthquake.

Date	*Item interested*	*Accident description*

C) ENVIRONMENTAL IMPACT

5) For the environmental protection, the owner shall demonstrate to have adopted opportune protective and preventive measures; *OR* Proceed with a vulnerability analysis of the conditions of water and soil around the site:

- Indicate the depth and the direction of the phreatic aquifer nearby the plant, in a sector with 30° degrees of amplitude and 3 kilometres of extension, measured from the possible point of release in the direction of the aquifer flow;
- Indicate the presence of wells inside the same sector, within an extension of 500 metres
- Indicate the presence of drains in superficial creeks or canals.

5.3 NaTech compatibility

The impact of risk interactions as natural hazards triggering technological events can be evaluated at local level through a semi-quantitative approach, based on a common rating scale for risks and risks interactions:

- $0 < I \leq 0.99$: Negligible
- $1 < I \leq 1.99$: from Low to Moderate
- $2 < I \leq 2.99$: from Moderate to High
- $I \geq 3$ onwards: from High to very high.

5.3.1 Risk rating

In order to evaluate the impact, each risk has to be rated keeping into account different aspects:

1) The possible strengthening effects (SE): "inherent local characteristics" of the risks that could produce an increase in the final impact.
2) The relevant past events (HE): recurrence of the events on the territory, keeping into account existing sectorial plans and surveys, integrated with the analysis of recent events.
3) The protection measures (PM): some risks could be reduced through barriers, i.e. industrial risks, flood, etc.

The rating criteria were defined for two of the natural risks related to climate change and relevant tor Natech events (flood, extreme weather) and for industrial accidents. The extreme events related to climate were analyzed through a simplified approach, aimed at keeping into account the increasing tropicalization of climate (Table 8).

Table 8: Criteria for the rating of Natech risks

Macro-Category	Rating		
	Low to moderate	**Moderate to strong**	**Strong to very strong**
	1 < I ≤ 1.99	**2 < I ≤ 2.99**	**I ≥ 3 onwards**
INDUSTRIAL RISK			
SE - Strengthening effects	Few items having the potential of major accident scenarios; scenarios related to flammable substances, with a reduced area of impact.	Items having the potential of major accident scenarios; scenarios related to flammable and environmental substances	Huge quantities of hazardous substances. Several items with the potential of major accident scenarios. Toxic release scenarios and / or with a great impact area.
HE -Historical events	No major accidents recorded.	Only low impact major accidents with no effect outside the site recorded.	High impact major accidents with effects outside the site recorded
PM - Protection measures	No dedicated measures for major accidents; no protective measures for the environment	Good safety level, in part effective also towards major accidents	Preventive measures adequate for avoiding major accidents and domino effects
FLOOD RISK			
SE - Strengthening effects	Interaction with low or reduced criticalities; hydraulic devices in good state; no or few critical points	Interaction with hydraulic control devices with moderate criticalities; critical points	Problematic interaction, recognized high critical areas, reported in Flood plans. Hydraulic devices in bad conditions, with recognized criticalities
HE -Historical events	Rare main flood events, return time of Flood management plans is confirmed	Floods of moderate impact, and/or in areas not included in Plans, short return time (≥ 50 years)	Events with return time > than that of the Flood management plan worst zone.
PM - Protection measures	No water regulation artefacts / systems or insufficient number/way. Criticalities and inadequate safety level	Water network / river / creek is properly controlled, the artefacts do not show relevant criticalities	The management of the water network / river / creek is well coordinated, evidencing no criticalities
EXTREME CLIMATE EVENTS			
SE - Strengthening effects	When no data on specific local trends are available, adoption of a unique value for the Strengthening effects, aimed at evidencing the increasing tropicalization, which could produce a major intensity and therefore major consequences for climate related events like i.e. raining, lightning, extreme temperatures etc		
HE -Historical events	Continental climate (Plane zones)	Climate with elevate temperature and/or with relevant temperature gaps: arid continental climate / cold continental climate / Mediterranean climate / mountain climate	Climate characterized by extreme temperature conditions / raining / intense storms: Tropical climate / equatorial climate / Desert climate / Subpolar climate
PM - Protection measures	-	-	-

As far as it concerns Industrial risks, both Seveso and non-Seveso installations shall be taken into account for the Rating assignation. As far as it concerns non-Seveso plants, no scenarios are available, but the identification of the possible installations prone to major accident hazards may be performed through the checklist (Par. 4.1). Consequently, the investigation through the Natech questionnaire (par. 4.2) provide enough information to estimate if:

- The type and quantity of substances detained, the type of process and storage, the type of items make the installation vulnerable to major accidents events (SE - Strengthening effects);
- The site has been interested by accidents, even provoked by external events (HE - Historical Events);
- The site has adopted preventive and protective measures against major accidents, including those with environmental impact, also addressing potential Natech scenarios (PM - Protection Measures).

5.3.2 Assessment of interactions

The ratings assigned to the macro-categories SE, HE, PM are used to assess the interaction between risks, intended as impact of a risk on another one. In the areas of risks overlapping, the average sum of the macro-categories of each risk is developed according to Eq. 1 below:

$$[1]\ Interaction = [(HE_{R1} + HE_{R2}) * 2 + (SE_{R1} + SE_{R2}) * 1 + (PM_{R1} + PM_{R2}) * 0{,}5]/6$$

Since the information needed to estimate the macro-categories differs in terms of reliability and each macro-category can differ in terms of influence on the final impact, weights were defined. These range from 0 to 2, in order to be aligned with the general scale adopted within the methodology. The attribution of the weights, proposed and validated through experts' judgement, was based on the following principles:

- Strengthening Effects (SE) = weight 1. SE intends to evidence important elements that increase the final risk impact, that could have been neglected by the sectorial plans.
- Historical events (HE) = weight 2. Despite climate change is affecting the estimation of return-times and probabilities for many events, HE is the most reliable category to assess, supported by specific studies, surveys and observations.
- Safety barriers = weight 0.5. Protection measures and safety barriers can undergo unexpected malfunctions, and they are typically not designed for multiple-risk events.

The influence of the weights assigned was assessed by a sensitivity test, discussed elsewhere (Pilone et al., 2019).

The formula of the binary interaction can be applied in every area of the territory where risks overlay; a dedicated Binary Interaction table shows all the possible interactions identified in a specific location. Table 9 represents an example of binary interaction related to Natech: the possible impact of flood and extreme climate events on an industrial plant was calculated. In this case, since the flood events had low energy, the possible influence Flood → Industry resulted having a medium-low impact (1.98).

Table 9: Example of binary interaction table

			Flood			Industrial			Climate events		
Interactions		→	SE	HE	PM	SE	HE	PM	SE	HE	PM
			3	2	0	2.8	1.5	-1.8	2	1	0
Flood	SE	3									
	HE	2	No interaction			1.98			No interaction		
	PM	0									
Industrial	SE	2.8									
	HE	1.5	No interaction			-			No interaction		
	PM	-1.8									
Climate events	SE	2									
	HE	1	1.83			1.48			No interaction		
	PM	0									

5.3.3 Assessment of Natech spatial consequences

Natech events are connoted by cascading scenarios and unexpected consequences that make difficult to define a clear spatial extension of the event; however, since planning discipline is funded on defining spatial functions and destinations, an estimation of the possible extent of consequences of Natech events is essential to give planners a correct perception of the risk, and allow them to take adequate countermeasures.

Two software released by the United States Environmental Protection Agency, ALOHA and HSSM, may be used to define the possible spatial consequences of Natech scenarios: the first simulates toxic and flammable releases, the second addressed environmental pollution in terms of dispersion of hazardous substances in groundwater. Neither ALOHA and HSSM are conceived to explicitly assess the consequences of Natech events (i.e. ALOHA cannot simulate a pool-fire on water, damages different from the release from a hole etc.), therefore several assumptions and simplifications were used to conduct the simulations for Natech events. In order to shape possible spatial consequences, it was firstly necessary to associate the value of binary interaction obtained with a possible damage state of the industrial items. Only the damage on tanks was considered: being the most vulnerable items for NaTech events, a formalization of their possible damage states was available. Antonioni et al., 2009, and Landucci et al., 2012, described three possible damage states, depending on the level of impact both of flood and earthquake. Each damage state was coupled with a level of interaction, as shown in Table .

Table 10: level of interaction associated to possible damage states on tanks

DAMAGE STATE		INTERACTION VALUE	
R3	continuous spill from a hole with diameter 1 cm	1 ≤ I ≤ 1.99	Low to Moderate
R2	loss of containment in more than 10 minutes	2 ≤ I ≤ 2.99	Moderate to High
R1	complete loss of containment in less than 10 minutes	I > 3 onwards	High to very high

Table 11 reports the input data assumed to run the software ALOHA and HSSM: as previously mentioned, both the programs were used to simulate the extension of the impact for a release from a tank, consequent to an earthquake or a flood event.

Table 11: Parameters for the estimation of NaTech spatial consequences

Interaction level	*Damage state*	*ALOHA*	*HSSM*
1 ≤ I ≤ 1,99	R3	*Source*: tank *Release hole:* 10 mm, or minimum hole area able to produce effects (20-30 mm)	*Source:* puddle Diameter calculated with ALOHA for 1 cm release. *Depth*: 5 mm (conventional ALOHA depth)
2 ≤ I ≤ 2,99	R2	*Source:* tank *Release hole:* minor damages = 150 mm or 225 mm or 300 mm, see U.K. HSE, 2012.	*Source:* puddle Diameter calculated with ALOHA for 150/225/300 mm. *Depth:* to be assessed
I > 3 onwards	R1	*Source:* puddle (more suitable to represent the catastrophic scenario correspondent to R1). *Diameter:* containment basin diameter Volume: total volume of substance contained in the tank	*Source:* puddle Diameter equal: containment basin diameter *Depth:* calculated through volume of the substance / area of the containment basin

ALOHA returns damage areas related to flammable substances and/or toxic releases that can be directly exported in ArcGIS® or in Google Earth. Despite they are only indicative of the possible impact area of a NaTech accident, at least they provide planners with a clear advice on the most vulnerable areas in the surroundings of the plant. As far as Natech scenarios causing damage to the environment are concerned, the multiple variables that connote the penetration of pollutants into soil and water make impossible a precise estimation of the actual behaviour of the pollutants; very complex models should be employed. The authors chose to apply a simpler software, HSSM, that can estimate the quantity of pollutant that contaminate groundwater only for LNAPL - Light Non-Aqueous Phase Liquids, as benzene and other low-molecular weight hydrocarbons. HSSM returns both the time employed by the pollutant to reach the water-table and the extension of the spreading of the pollutant in the underground aquifer.

5.3.4 Compatibility assessment

The compatibility of risk interactions and urban and environmental vulnerable elements is developed on the basis of the Interaction tables and of the related GIS maps. A threshold of 2.5 (corresponding to a medium to high risk) was established: if the risk macro-categories Strengthening Effects and Historical Events, or the Interaction values overcome the threshold, this should be interpreted as the signal of a potential incompatibility with vulnerable elements. Further details for the procedure of compatibility assessment can

be found in Pilone & Demichela, 2018, and Pilone et al., 2018. In case the application of HSSM and ALOHA is not possible due to the limits of the software or the lack of data, the threshold is evaluated inside a buffer zone of 500-1000 m around the installations. Inside this area, the vulnerable elements exposed are identified and it is assumed that the values of the Interaction and of the Industrial risk macro-categories are applied. Then, the potential situations of incompatibility are identified. The extension of the buffer-zone derived from the distance applied for the Emergency plans of Seveso installations.
Figure 4 shows an example of buffer zone of 500 m applied to a Seveso plant, with the related Compatibility assessment, shown in Table 12. In the example here reported, the risk interaction was below the threshold value of 2.5, but the Industrial risk Macro-category SE was higher than 2.5. Some incompatibilities were detected both for the environment and for two buildings.

Figure 4: Example of buffer zone for a Seveso plant

Table 12: Example of compatibility assessment and planning actions

Ratings	***Territorial vulnerabilities inside the buffer zone (500 m)***	***Environmental vulnerabilities inside the buffer zone (500 m)***
Interaction F→I 1,98 *Industrial risk* SE 2,8, HE 1,5 *Flood risk* SE 3, HE 2 *Variations inside the buffer area* Area partially interested by Flood	AREA: residential areas – medium density; 2 productive areas, destined for reconversion to commercial function, whose transformation must be monitored. PUNCTUAL: 2 buildings with medium-high frequency of people (commercial centre/ bowling; church) INFRASTRUCTURES: Electric power lines	RV – water table depth < 3 m. Presence of a canal for irrigation adjacent to the northern border of the plant
	Territorial compatibility	***Environmental compatibility***
COMPATIBILITY	Potential incompatibility in case of toxic release for the two buildings (threshold for S.E. > 2,5). An in-depth analysis is recommended for: 1) the specific activities and frequency of the 2 vulnerable elements classified; 2) the storage methods and protection and preventive measures of the substances classified as TOXIC (H2)	The plant, detaining toxic substances and substances dangerous for the environment, is not compatible with the vulnerable element identified. S.E. = 2.8 overcomes the compatibility threshold; the interaction with flood events, even if connoted by a low-medium value (1.98), could enhance the threat. Further analysis on the possible pollution scenarios and prevention and protective measures against flood should be carried out.

5.4 Identification of Natech scenarios

The 'Natech tool' for planners presented in the previous section aims at helping them in quickly identify possible Natech events on their territory and obtaining an indicative idea of their spatial impact and consequences. However, in case compatibility issues are identified, an in-depth analysis should be carried out.

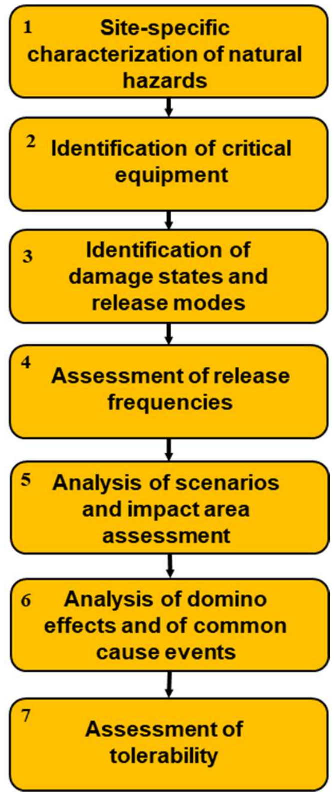
The first phase of the analysis consists of an investigation of the vulnerable elements and of the industrial plant itself to verify if the incompatibility emerged in the previous phases of the methodology is confirmed. The actions to be carried out are reported in the following Table :

Table 13: Actions for a detailed assessment and management of industrial risk

STEP 1: DETAILED ANALYSIS OF THE INDUSTRIAL SITE		
RISK	*In presence of vulnerability centers and/or high population density*	*In presence of Environmental elements*
Industrial	When the threshold values for compatibility are exceeded, a more detailed assessment of the vulnerable elements and of the plant is needed in terms of: 1) characteristics of the vulnerable elements (i.e. for infrastructures: quantification of people, type of structure, position of openings etc (Ministero lavori pubblici, 2001, Bonvicini et al, 2012) 2) position and characteristics of the storage tanks of concern 3) specific scenarios that could affect the vulnerable elements 4) Preventive and protective measures likely to be effective during the Natech event and already in place	The operators should carry out a detailed investigation of the potential environmental impact of the facility, assessing water and soil conditions around the plant in terms of: 1) depth and direction of the groundwater table nearby the plant, in a sector with 30° of amplitude and 3 kilometers of extension, measured from the possible point of release in the direction of the aquifer flow; 2) presence of wells inside the same sector; 3) presence of drains into superficial creeks or canals. If other environmental vulnerable elements are identified by land-use planning regulations, the compatibility with scenarios and substances detained by the plant shall be analyzed in detail.

In case the compatibility issues are confirmed (i.e. the more precise impact areas still include the vulnerable elements), it is necessary to elaborate a quantitative assessment of Natech scenarios. The outline of the procedure is shown in Figure 8, while a step-by-step description of the procedure and the calculations are reported elsewhere (Antonioni et al., 2015, Cozzani et al., 2014, Cozzani and Salzano, 2016). The procedure is based on the simplified description of the intensity of the natural hazards by intensity parameters and time of return, and on the identification of the Natech-specific loss of containment scenarios that may affect the surroundings of the site. Specific scenarios and software for consequence analysis are needed to carry out the assessment. This phase of the methodology requires the involvement of Natech experts and should be developed in the context of a concerted procedure between companies and regional/local authorities. The outcomes of the integrated quantitative assessments of Natech scenarios can provide local planners with clear indications about the effective Natech risks related to the installations, allowing them to adopt measures both to reduce the risk (installation of Natech-specific safety barriers at the facility) or for planning (limitation in land-use around the installation, check of the safety distances of lifelines as water and natural gas supplies, and of infrastructures as highways or railway lines, etc.). The emergency plans should be revised (specifically, the Municipal emergency plan and of the Emergency plan for the installation) accordingly considering the specific conditions of the emergency management during Natech events (e.g. presence of flood water, disruption of roads and bridges, etc.).

Figure 8: Procedure for the detailed assessment of Natech scenarios



6. CASE STUDY: MANTUA PETROCHEMICAL PLANT

The methodology exposed in Par. 5 was applied by the authors to the important productive hub of Mantua, where several hazardous industries are present; in particular, two Seveso plants (a petrochemical establishment and a gasoline and diesel warehouse) provoked during the years a severe environmental pollution of the underground aquifer and soil. The petrochemical plant was therefore analysed to verify if the methodology proposed was able to correctly describe possible incidental events and to identify unforeseen interactions with the natural risks.

6.1 NaTech compatibility

The information related to Mantua petrochemical plant unfortunately could not be directly collected among the industry itself with the Na-tech questionnaire, but the quantity of substances detained, types and distribution of the items, processes etc. were retrieved from the documents for the release of IPCC authorization and in the Municipal plan related to hazardous industries. The petrochemical plant is active from the end of the Fifties; its production is organized in three different cycles: 1) styrene monomer; 2) styrene polymers; 3) intermediate products (phenol, acetone, etc.). The productive cycle of "styrene monomer" employs as raw materials ethylene and benzene, transforming them into ethylbenzene and finally into styrene monomer. This substance is the raw material for the cycle "Polystyrene": it is polymerized, also with acrylonitrile and rubber, to obtain several types of Styrofoam, addressed to automotive, house and packaging sectors. The productive cycle "Intermediate products" is based on cumene and hydrogen (obtained from the de-hydrogenation of ethylbenzene), whose transformation returns phenol, acetone, alpha-methylstyrene, acetophenone, cumene hydroperoxide, cyclohexanol, cyclohexanone. The plant has a storage park with capacity equal to 170.000 m^3; it also hosts a research centre with pilot equipment, a plant for the water treatment connected to an incinerator, plants for the production and distribution of water (demi, industrial).

6.1.1. Risk rating

The following Table 14 describes the ratings assigned to the Macro-categories representing the Industrial risk related to the petrochemical plant: the first column shows the macro-category *Strengthening effects*, evaluated on the basis of the items, type and quantity of substances (toxic, flammable, dangerous for the environment), and scenarios. The second column is related to the *Protection measures*, both adopted for the single item, or general for pollution and NaTech events. The third column is related to all the accidental events registered for the plant.

Table 14: ratings of the macro-categories S.E., H.E. and P.M. for Mantua petrochemical plant

S.E. STRENGTHENING EFFECTS				P.M. PROTECTION MEASURES		H.E. HISTORICAL EVENTS
Assets / items with potential NaTech risk		Substance	Scenarios	Protection measure related to the item	Protection measures for Na-tech / pollution events	
No	Item description					
2	Fixed roof tanks = 1500 m^3	Acrylonitrile	Toxic release	Waterproof containment basins. Double bottom, insulation.	NATECH: No specific measures were adopted for flood events. Concerning the table reported in (Cruz et al., 2004), only 10/31 measures can be considered adopted; no structural interventions were made on the tanks, like anchoring or construction of containment walls. No intervention is mentioned against lightening POLLUTION: 15/22 measures recommended by (Provincia di Torino, 2010) were adopted	VERSALIS is included in Mantua national area of decontamination (SIN), which is affected by a at least 30-years of pollution. Despite of the containment barriers and protective measures imposed by the Government, the piezometers still register parameters for benzene and other hazardous substances higher than the thresholds. As far as it concerns floods, according to (ENI Versalis, 2013), the maximum height reachable by Mantua lakes during an exceptional raining event, with return time = 100 years and last d = 96 ore, could go from m 18,50 to m 19,00. Since Versalis plant is located on a river terrace whose heights vary from m 22,00 to m 23,00, the hydraulic risk for the plant was excluded. However, the calculation did not take into account the possible obstruction of Scaricatore Vallazza-fissero
5	Floating roof tanks = 27000 m^3	Benzene	n.a.	Non-waterproof containment basins. Double bottoms.		
4	Floating roof tank = 17000 m^3	Ethylbenzene	n.a.			
6	Floating roof tanks = 10000 m^3	Toluene	n.a.			
1	Floating roof tank = 5000 m^3	Styrene	n.a.			
3	Fixed roof tanks = 8000 m^3	Cyclohexanone	n.a.	Non-waterproof containment basins. Double bottoms, insulation.		
2	Fixed roof tanks = 2000 m^3	Olone - KA oil	n.a.			
5	Floating roof tanks = 26000 m^3	Cumene	n.a.	Non-waterproof containment basins. Double bottoms		
7	Fixed roof tanks = 16000 m^3	Styrene	n.a.	Ground containment basins. Double bottom; insulation		
1	Floating roof tank = 500 m^3	Benzene	n.a.	Ground containment basins. Double bottom;		
1	Floating roof tank, 500 m^3	Cumene)	n.a.			
3	Horizontal tanks = 351 m^3	Pentane	n.a.	Ground containment basins.		
10	tanks with fixed roofs, 75 to 770 m^3	Styrene, benzene	n.a.	Waterproof basins.		
8	tanks with fixed roofs, 45 to 1000 m^3	Styrene, benzene (F)	n.a.	Waterproof basins.		
30	tanks with fixed roofs, 100 to 1000 m^3 (phenol)	alpha methyl styrene, phenol, cumene, Hydrocarbons	Releases from ducts	Waterproof basin with containment walls		
14	tanks with fixed roofs, to 1000 m^3		n.a.	Waterproof basin with containment walls		
20	pressurized tanks, capacity from 4 to 120 m^3 (styrene)	alpha methyl styrene, styrene, ethylbenzene	n.a.	Waterproof pavements, connected to the oily drainage system		

S.E. STRENGTHENING EFFECTS				P.M. PROTECTION MEASURES		H.E. HISTORICAL EVENTS
Assets / items with potential NaTech risk		Substance	Scenarios	Protection measure related to the item	Protection measures for Na-tech / pollution events	
No	Item description					
9	pressurized and fixed roof tanks, capacity from 0,15 to 10 m^3 (pentane)	Styrene Pentane	n.a.	Waterproof pavements.		
9.	fiberglass tanks, capacity from 28 to 150 m^3 (pentane)	Hydrochloric acid, sodium hypochlorite	n.a.	Containment basin in concrete		
-	Pipelines, diameter 150 mm; - Pressurized pipeline ethylene, towards areas ST20 e ST40	Cumene benzene ethylbenzene	n.a.	n.a.		
-	Pipelines on racks - 5 m.;	Various (F, N)	Leaks and toxic release	n.a.		
7	Distillation towers	Phenol, styrene	n.a.	n.a.		
1	Quay for the uploading and downloading	Acetone, styrene, ethylbenzene	n.a.	n.a.		
1	Incinerator and torches	Hazardous wastes	n.a.	n.a.		
1	Drainage oily and acid basins and tanks	Polluted liquids	n.a.	n.a.		
SCORE						
3				-1		2

The petrochemical plant received a high score for the macro-category *Strengthening effects* (3): in fact, it detains a huge amount of hazardous substances (toxic, carcinogenic, hazardous for the environment and flammable), representing multiple sources of hazard; in addition, its items are particularly vulnerable to external impacts (tanks and pipelines of the storage park, mainly located on a non-waterproof basement, the multiple distillation towers that could be hit in case of earthquake, the open sky basins for the water treatment etc.).

A medium-high value (2) was assigned for the macro-category *Historical Events*; indeed, even if the most dangerous productions are ceased, and the plant adopted more precautionary measures with respect to the past, the yearly surveys demonstrated no sensible diminution of the pollutants, in particular for benzene, therefore the plant still represents a source of pollution.

For the *Protection measures*, the petrochemical plant adopted several measures to contain the pollution, however fewer interventions could be considered valid to face NaTech effects. The major criticalities concern the non-waterproof areas of the plant (i.e. the storage park), and the lack of preventive measures against flood in some crucial departments close to Mincio river (i.e. the incinerator, the water treatment plant etc.). Therefore, for precautionary reasons, PM macro-category received a low value (-1).

The petrochemical plant could be subject to three types of external natural events: earthquake, flood and climate-related events like violent storms, heat waves etc. The macro-categories of each Natural risk were rated too, but the tables are not reported here for reason of space; a brief explanation concerning the ratings assigned is reported below:

- EARTHQUAKE → low energy seismic events reached Mantua in the remote past, but in 2012 a huge earthquake with epicentre at 50 km from Mantua led to the seismic re-classification of all the Region, until then considered with a low seismic risk. Ratings attributed: *S.E. Strengthening effe*cts = 2; *H.E. Historical events = 1; P.M. Protection measures = 0.*

- FLOOD → Mincio hydraulic flow is almost completely artificial because it is regulated from the beginning with a series of dikes and spillways. Consequently, the probability of flood is extremely low, but the Climate change is progressively worsening the situation because the hydraulic system is subjected to an increasing stress due to the high quantities of water discharged by the city sewages. Ratings attributed: *S.E. Strengthening effects* = 1,5; *H.E. Historical events = 1; P.M. Protection measures = -3.*
- CLIMATE RELATED EVENTS → the ratings were assigned in order to reflect the effects of the Climate change: even if until now storms and other phenomena haven't produced particular severe events, their strength and frequency is increasing because of the Climate change. Ratings attributed: *S.E. Strengthening effects* = 2; *H.E. Historical events = 1; P.M. Protection measures = 0.*

6.1.2. Assessment of the interactions

The following table 15 analyses the value of possible interactions between the natural risk and the industrial risk in the area of the petrochemical plant.

Table 15: binary interactions in the petrochemical plant area

HAZARDS & Macrocategories			Seismic			Flood			Industrial			Climate events		
			SE	HE	PM	SE	HE	PM	SE	HE	PM	SE	HE	PM
			2	1	0	1,5	1	-3	3	2	-1	2	1	0
Seismic	SE	2	No interaction			1,00			1,75			No interaction		
	HE	1												
	PM	0												
Flood	SE	1,5	No interaction			No interaction			1,42			No interaction		
	HE	1												
	PM	-3												
Industrial	SE	3	No interaction			No interaction			-			No interaction		
	HE	2												
	PM	-1												
Climate events	SE	2	No interaction			1,00			1,75			No interaction		
	HE	1												
	PM	0												

The values obtained for the effects of the binary interactions are between Low and moderate (1 < I ≤ 1.99); they reflect the low incidence of the natural hazards in the zone analysed, therefore the methodology returned a credible result.

6.1.3. Spatial consequences of the interactions

HSSM and ALOHA simulations were carried out to verify the possible spatial consequences of natural events impacting on the petrochemical plant. This step was executed to acquire more precise information for the compatibility assessment.

Since the interactions obtained from Table 15 have values between 1 and 1,99 (Low to moderate interaction), the damage state corresponds to R3 '*Continuous spill from a hole with diameter 10 mm'* both for seismic and flood risk (see Table 10). ALOHA simulations were carried out for R2 damage states too, in order to verify the impact of extreme events; HSSM was executed only for the R3 damage state provoked by Earthquake (S), due to the software limitations that do not allow simulations of releases on water.

The items taken into account for the analysis were the tanks of the petrochemical storage park; in addition, a simulation was carried out for the rail tankers that enter the petrochemical plant in proximity of some residential areas.

The following Table 16 summarizes the parameters settled to carry out HSSM and ALOHA simulations for the petrochemical plant.

Table 16: Parameters for HSSM and ALOHA simulations

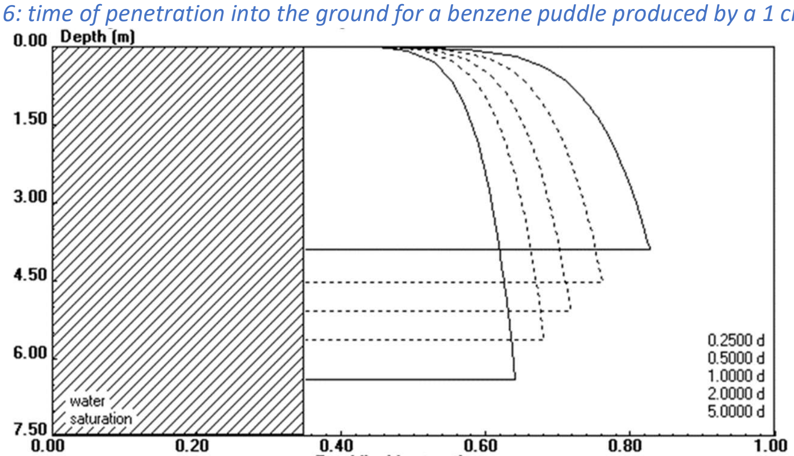
Damage state	**ALOHA**	**Natural risk**		**HSSM**	**Natural risk**	
	Parameters	***S***	***F***	***Parameters***	***S***	***F***
R3 (binary interactions)	*Source*: tank *Release hole:* 1 cm-3 cm	✓	✓	*Source:* puddle for 1 cm release. *Depth*: 0,5 cm (conventional ALOHA depth)	✓	×
R2 (multiple interactions)	*Source:* tank *Release hole:* 15 cm-22,5 cm-30 cm	✓	✓	*Not executed*	×	×

As far as it concerns the energetic/toxic consequences, ALOHA pointed out that seismic external accidents involving tanks and rail-tankers of acrylonitrile and benzene could generate toxic external consequences (Figure 5). The protection measures implemented for the acrylonitrile tanks (survey of leakages through gas chromatography, double bottom etc) could grant a rapid intervention to avoid the scenario, but the railway is actually vulnerable in case of interaction effects, because no containment basins or direct control are available.

Figure 5: Seismic R3 damage state on acrylonitrile and benzene rail-tankers

HSSM returned an alarming scenario for the environmental pollution: due to the scarce depth of the aquifer, the puddle produced by a release from a hole of 1 cm, after 3 hours of stay on the ground, is sufficient to push the pollutant into the aquifer (Figure 6). The data obtained with HSSM confirmed the situation of severe environmental pollution registered for Mantua industrial hub: considering that small releases could not being detected in time by the monitoring and protection devices, it is very important to duly take into account this scenario for the compatibility phase.

Figure 6: time of penetration into the ground for a benzene puddle produced by a 1 cm hole



6.1.4 Compatibility assessment

The neighborhood of the petrochemical plant is connoted by a wide industrial presence; inside the 500 m buffer zone, few residential areas are present (see orange areas in Figure 7), and no buildings at high frequentation were identified. The scenarios obtained through ALOHA and HSSM were superimposed to the territorial vulnerable elements identified to assess potential incompatibilities (see Table 17 below).

Figure 7: buffer zone and territorial vulnerable elements around the petrochemical plant

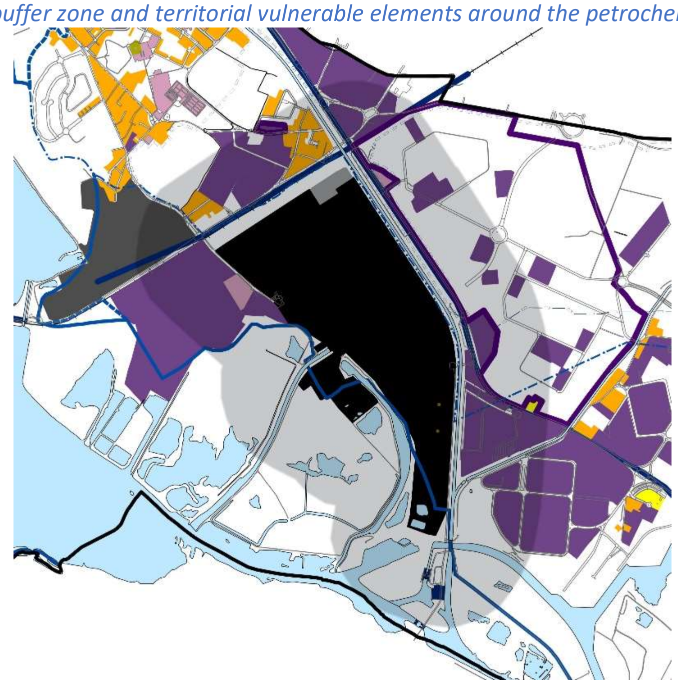


Table 17: Vulnerable elements and incompatibilities of the petrochemical plant

Territorial vulnerabilities inside the buffer zone (500 m)	***Environmental vulnerabilities inside the buffer zone (500 m)***
AREA: residential areas (B) included in the buffer zone of 500 m from the Seveso industries. The City Plan identified a huge area adjacent to the east border of the petrochemical plant for the placement of commercial and industrial activities. *Punctual elements classified as A or B:* only few C punctual elements were identified. *Linear elements and strategic areas / building / infrastructures:* railway, Mantua orbital road, methane pipe line, services line to the plants	1. Protected area SIC/ZPS Vallazza; 2. Mincio protected park 3. Wooded areas included 4. Area subjected to hydrogeological restrictions ex l.r. 45/1989: coastal banks of Mincio River 5. Mincio river and the lakes constitutes a passageway for several wild species, in particular birds 6. Soils with Land Use Capacity 1 or 2 7. The vulnerability of the aquifers in the area is High *8.* The level of the aquifer is between 4 m. and 8m.
Territorial compatibility	***Environmental compatibility***
Two incompatibilities along the North and East borders of the petrochemical plant were encountered, in relation to potential accidents provoked by the release of acrylonitrile and benzene from tanks and rail tankers. In particular, along the railway, the impact of natural external events could cause minor damage to the rail-tankers, producing release that could interest the residential areas classified as B. As far as it concerns the east border, releases from the tanks of acrylonitrile and benzene could interest some adjacent industrial activities and a residential house results involved.	**Environmental incompatibility** due to possible leakage, even in normal conditions, of pollutants into the soil, the superficial water and the underground aquifer. The current protective measures adopted (i.e. hydraulic barrier) seem to be not sufficient to face the situation.

6.1.5 Further NaTech analysis

For the case-study of Mantua petrochemical plant, the above described methodology evidenced possible critical situations that were not reported in the City plan and in the plans related to Flood and Seismic risk, related to the interaction between natural events and industrial risk. The presence of incompatibilities suggests that further analyses should be carried out. In particular:

FOR THE TERRITORIAL VULNERABILITY → investigation on the quantity, ageing and habits of the people living in the B residential areas nearby the railway, on the use of Frassine railway station, on the frequency of the arrivals of the dangerous goods etc. More detailed quantitative simulations on the possible scenarios related to the rail-tankers should be carried out too. Finally, possible integrative protection measures could be adopted by the petrochemical plant and by the Municipality, like i.e. improvement of the emergency procedures, check and possible substitution of the openings of the residential houses pointed towards the railway, the automatic lock of the ventilation systems, etc.

FOR THE ENVIRONMENTAL VULNERABILITY → The petrochemical plant is part of the Mantua national Site of Recovery, for which the Ministry of the Environment already recommended several monitoring plans and adoption of measures. A more rapid and efficient control on the monitoring plans and implementation of actions is certainly recommended. Therefore, the most adequate procedure to avoid the continuation of the pollution should be the complete impermeabilization of the storage parks and pipelines paths; since this is a costly operation, it could be at least proposed for the tanks and pipelines that transport the substances whose presence still result too abundant in the surveys campaign of the aquifer (like i.e. benzene).

7. CONCLUSIONS

Natech events are undergoing an increase due to climate change effects, and the preparedness to manage them is still not sufficient, even for the countries more aware of the problem. Krausmann et al., 2019, evidence that, despite scientists have started to join forces with industry and government to systematically assess and control Natech risk, the progress of NRM in EU Member States and OECD Member Countries still show deficiencies in existing safety legislation. Krausmann et al., 2019 recommended specific actions to improve the approach to Natech risk, in terms of:

- **Awareness** → Educational and awareness-raising campaigns evidencing the vulnerability of hazardous installations to natural hazards
- **Risk governance** → Territorial perspective in NaTech risk governance, safety of the hazardous installation integrated with that of its surroundings
- **Legal infrastructure** → Specific legislation for NaTech risk reduction, guidance on how to achieve the goals set out in the legal framework
- **Risk communication** → Improvement of the communication in industry and at all levels of government (national, regional and local); identification and sharing of the existing best practices for NaTech risk reduction
- **Risk assessment** → Development of methodologies and tools for NaTech risk analysis (damage functions and consequence-analysis methods for each natural risk) and NaTech mapping
- **Guidelines** → Guidelines for risk assessment in industry and territory, including NaTech scenarios for multiple minor or major natural-hazard triggers.
- **Data collection** → Promotion of an easy and open sharing of relevant data on technological risks.
- **Knowledge and skills** → Enhancement of the knowledge about NaTech risk reduction; training of the industry personnel, authorities in charge of chemical accident prevention and civil protection to tackle situations related to a NaTech accident.
- **Cooperation and partnerships** → Cooperation among all stakeholders, in particular at local level, to reduce NaTech risks. Creation of public-private partnerships, and regional and international networks for effective NaTech risk management

The ‘NaTech suite’ proposed in this paper answers to some of the objectives above reported: it intends to fill the knowledge gap related to Natech risks in the current land-use practices with a particular focus on local administrations. They can be considered the weakest link in the chain: on one side they are charged with several duties related to risks like i.e. emergency management, structural measures to contain the risk, correct land-use planning and management, but on the other side, they have poor resources to invest in research and innovative methods, and sometimes inadequate technical preparation and knowledge to manage the complexity related to multi-risk events. The effects of climate change are exacerbating and enhancing the probability for multi-risk events: the augmented recurrence and strength of events like storms, heavy rains or prolonged heatwaves have a deep influence on flood, landslides, storm surges, mega-fires, so that even areas till now considered as ‘safe’ are exposed to unexpected risks.
In a European and national context where an harmonized and clear legislation about adaptation and management of the effects of Climate change is still on progress, local administrations are often asked to face disasters with inadequate preparedness and obsolete planning and emergency tools, so that in the end the risk management is limited at the estimation of the cost of damages.

Hopefully, the existing gap at local stage could be soon filled by specific legislation; as mentioned in Par. 3.2, Natech events should be taken into account in this context. However, the implementation of the measures and procedures identified in each Member State for the National Adaptation Plans could take advantages from the adoption of a multi-level perspective to face multi-risks, as that proposed in this study.

NOTATIONS

ALOHA = (Areal Locations of Hazardous Atmospheres), computer program designed to model chemical releases for emergency responders and planners

ANCI = Associazione Nazionale dei Comuni Italiani (National Association of Italian Municipalities)

DM = Italian Ministerial Decree

EIA = Integrated Environmental Authorization

ERIR = Italian Plan for Safety distances around Seveso plants

EU = European Union

F = Flammable substance

GIS = Geographic Information System

HSSM = (Hydrocarbon Spill Screening Mode), computer program designed to simulate flow of LNAPL and transport of a chemical constituent of the LNAPL from the surface to the water table; radial spreading of the LNAPL at the water table, and dissolution and aquifer transport of the chemical constituent.

LNAPL = Light Non-Aqueous Phase Liquids

MiSE = Ministero per lo Sviluppo Economico (Italian Ministry of the Economic Development)

MATTM – Ministero dell'Ambiente e della Tutela del Territorio e del Mare (Italian Ministry of the Environment)

MIT – Ministero delle Infrastrutture (Italian Ministry of Infrastructures)

N = Noxious substance

NAP = Italian National Adaptation Plan (PNACC = Piano Nazionale di Adattamento ai Cambiamenti Climatici)

NaTech = Technological Hazards triggered by Natural Events

OECD = Organization for Economic Co-operation and Development

QRA = Quantitative Risk Assessment

T = Toxic substance

[*Macro-categories for the methodology:* SE = Strengthening effects; HE = Historical and recent events; PM = Protection measures]

[*EU Member States:* BG = Belgium CZ = Czech Republic, DE = Germany, DK = Denmark, FI = Finland, FR = France, HU = Hungary, IE = Ireland, LT = Lithuania, LU = Luxembourg, LV = Latvia, NL =Netherlands, PT = Portugal, RO = Romania, SE = Sweden, SI = Slovenia, SK = Slovakia, UK = United Kingdom]

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Industrial activity	***IPPC***		***NOSE-P process***	***Main substances***	***Items / processes vulnerable for NaTech risk***	***Items position***		***Vulnerable to:***	***Possible consequences***
	Cod.	***Description***				***Inside***	***outside***		
TEXTILE INDUSTRIES									
Preparation and spinning of textile fibers	6.2 6.7	Plants for pre-treatment or dyeing of fibers or textiles	Manufacture of textiles and textile products	1) Sizing: acrylic or resin-like starches or polyvinyl alcohol or carboxymethyl cellulose 2) Purge: sodium hydroxide, sodium carbonate 3) Bleaching: chlorine or perborate compounds and phosphates 4) Dyeing: Colorants	Process basins for Sizing; Purge; Bleaching and Dyeing	x		Earthquake	Cracking of process basins; possible leakage and pollution of soil and waters in case of absence / breaking of containment basins
					Plants for the physical and chemical treatment of waste water		x	Earthquake Floods	Cracking / braking of the basins Overflowing in case of flood / heavy rain Possible pollution soil / water
Finishing of textiles	6.2	Plants for the pre-treatment or dyeing of fibers or textiles; Plants for surface treatment of products using organic solvents	Manufacture of textiles and textile products; Textile finishing or leather tanning (Solvent use)	1) Finishing: resins (acrylic, vinyl, urea or other), or addition of inorganic substances, such as phosphorus and silicon compounds	Process basins for finishing: chemical or physical treatments	x		Earthquake	Cracking of process basins; possible leakage and pollution in case of absence / breaking of containment basins Cracking of storage tanks / cylinders, connection lines
					Plants for the physical and chemical treatment of waste water	x	x	Earthquake Floods	Cracking / braking of the basins Overflowing in case of flood / heavy rain Possible pollution soil / water
MANUFACTURE OF LEATHER AND SIMILAR ITEMS									
Preparation and tanning of leather	6.3 , 6.7	Leather tanning plants; Plants for Surface treatment using organic solvents	Production of leather and manufacture of leather products Textile finishing or leather tanning (use of solvents)	Natural tannins, synthetic tannins, chromium salts, aluminium salts, zirconium salts, marine animal oils, formaldehyde	Drums and mixers (3,5 * 2,5 m) for leather impregnation and dyeing	x	x	Earthquake Floods	Cracking / breaking of drums and mixers
					Plants for the physical and chemical treatment of waste water	x	x	Earthquake Floods	Cracking of the catch basins Overflowing in case of flood / heavy rain Possible pollution soil / water
WOOD INDUSTRY AND WOOD AND CORK PRODUCTS (EXCLUDING FURNITURE)									
Cutting and planing of wood	-	-	-	-	Drying timber storage		x	Heatwaves Fires	Emissions deriving from combustion of wood

Industrial activity	IPPC		NOSE-P process	Main substances	Items / processes vulnerable for NaTech risk	Items position		Vulnerable to:	Possible consequences
	Cod.	Description				Inside	outside		
Manufacture of wood, cork, straw and plaiting materials	6.7	Surface treatment of products tr. organic solvents (dressing, printing, spreading, degreasing, waterproofing, gluing, painting, cleaning, impregnating)	Application of paints (Use of solvents); Degreasing, dry cleaning and electronics; Printing industry (Use of solvents	Organic solvents	Timber storage		x	Heatwaves Fires	Emissions deriving from combustion of wood
					Organic solvents storage (tanks, big-bags)	x	x	Flood fires earthquake	Emissions deriving from combustion of treated wood Cracking of storage tanks / cylinders, connection lines with possible pollution
MANUFACTURE OF PAPER AND CARDBOARD ARTICLES									
Manufacture of pulp, paper and cardboard	6.1	Industrial plants for the manufacture of pulp from wood or fibrous materials Paper and cardboards	Production of pulp for paper, paper and paper products	Bisulphites, sulphates, soda to produce chemical wood pulp	Vats for the pulp production	x		Earthquake	Cracking of process basins; possible leakage and pollution in case of absence / breaking of containment basins
					Storage of products for the treatment	x	x	Earthquake Floods	Cracking of storage tanks / cylinders, connection lines with possible pollution
					Plants for the physical and chemical treatment of waste water		x	Earthquake Floods	Cracking / braking of the basins Overflowing in case of flood / heavy rain Possible pollution soil / water
Manufacture of paper and cardboard articles	6.7	Surface treatment of products using organic solvents (dressing, printing, spreading, degreasing, waterproofing, gluing, painting, cleaning or impregnating)	Application of paints (Use of solvents); Degreasing, dry cleaning and electronics; Printing industry (Use of solvents	Organic solvents	Organic solvents storage (tanks, big-bags), pipelines	x	x	Floods Fires, Earthquake	Cracking of storage tanks / cylinders, connection lines with possible pollution
					Plants for the physical and chemical treatment of waste water		x	Earthquake Floods	Cracking / braking of the basins Overflowing in case of flood / heavy rain Possible pollution soil / water